DRAFT

MANAGEMENT OF WASTE MATERIALS CONTAINING ELEVATED LEVELS OF RADIUM

I. Introduction

There are areas within the boundaries of the State of Oklahoma which have been identified as having low-grade uranium ore which is a source of radium. Solids from oil field brines containing radium may accumulate in equipment used in salt water injection projects in the oil fields. There were aircraft dial painting shops which used radium which generated waste which may need cleanup.

There are currently no state standards or guidelines for the management of such radium containing waste materials.

The Oklahoma Radiation Protection Regulations state "A user may dispose of radioactive waste by dumping or burial only in areas and by procedures approved by the Oklahoma State Department of Health."

II. Objectives

There are five (5) technical objectives which serve as the basis for the criteria for managing waste materials containing radium. These technical objectives are as follows:

1. Limit the misuse (inadvertent intrusion) of buried radium containing waste materials for an extended period of time.

2. Limit radon emissions from the surface of buried radium containing waste materials.

3. Limit external radiation exposure from the buried radium containing waste materials.

4. Limit the degradation of ground water quality resulting from buried radium containing waste materials.

5. Limit undue internal radiation exposure resulting from land used for agricultural purposes.

III. Discussion of Criteria

Criterion 1

"If the level of radium in the radium containing waste is 5 picocuries per gram (dry weight) or less, such radium containing waste may be disposed of only in an OSDH permitted sanitary landfill or as provided in Criterion 3. Housing restrictions will not be required."

The USEPA "Standards for Remedial Actions at Inactive Uranium Processing Sites", 40CFR 192.12, states that the concentration of Radium 226 shall not exceed 5 picocuries/gram (pCi/gm) averaged over the first 15 centimeters (cm) of soil below the surface and shall not exceed 15 pCi/gm averaged over 15 cm thick layers of soil more than 15 cm below the surface.

These criteria apply to cleanup of land (away from the tailings piles) where homes could be built.

The Conference of Radiation Control Program Directors, Committee on Natural Radioactivity Problems, Report No. 2, August 1981, states that removal or controls for soil containing up to 3 pCi/gm of Radium 226 would not be mandatory. If the concentration of Radium 226 exceeds 6 pCi/gm, removal or other controls would then be mandatory.

The USEPA "Final Environmental Impact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (EPA 520/1-83-008-1, September 1983), indicates that houses built on land with a concentration of 5 pCi/gm radium would be expected to have indoor radon decay product levels of approximately 0.02 Working Level (WL).[1] ("Working Level" (WL) means any combination of short-lived radon decay products in one liter of air that will result in the ultimate emission of alpha particles with a total energy of 1.3×10^5 MeV.) The estimated residual risk of lung cancer due to a lifetime exposure to this level is approximately 2 in 100.[2]

The gamma radiation levels (from the radium containing waste) to individuals living above such a concentration of radium would be approximately 80 millirem/year (mrem/yr).[3]

The radium containing waste will be placed in an OSDH permitted sanitary landfill which is designed to have an approximately 5-10 foot thick clay liner to protect against groundwater movement (permeability $<1 \times 10^{-7}$

cm/sec). In addition, the landfill will have a final cover of at least two feet of soil.

The design of such a landfill results in protective measures in excess of those required by the USEPA for cleanup of land containing uranium mill tailings. For example, placing a 24 inch cover of regular soil over the radium containing waste will reduce the radon emanation by approximately 57% (to 0.0086 WL)[4] or approximately 2.2 picocuries/meter^2-second (pCi/m^2-sec), while the external gamma radiation levels would be reduced to less than 3% or original[5], excluding natural background.

Should the final cover be removed in later years, the radium concentration levels would still not exceed 5 pCi/gm.

(NOTE: Calculated values, as presented in this document, may differ from actual values due to varying environmental factors.)

Criterion 2

"If the level of radium in radium containing waste is greater than 5 picocuries per gram (dry weight) but less than 50 picocuries per gram (dry weight), such radium containing waste may be disposed of only in an OSDH permitted sanitary landfill or as provided in Paragraph 5 (Criterion 4). There shall be at least three meters of non-contaminated soil between the radium containing waste and housing level such that reasonable assurance has been provided that the exhalation rate of radon to the atmosphere or into a dwelling will not exceed an average release rate of 5 picocuries/square meter/second."

Due to the fact that radium containing waste containing up to 50 pCi/gm of radium may be buried in a "non-radioactive waste" landfill, and one cannot be assured of control of the site for an extended period of time, it is essential that the landfill be designed such that unintentional intrusion into such radium containing wastes would be limited. Human activities usually involve excavation to depths of 6 to 8 feet (e.g., utility lines, basements, graves, etc.). Therefore, to prevent casual intrusions into the radium containing wastes, as well as to prevent erosion, a final cover of 3 meters (below grade level) is stipulated. This is consistent with the USEPA guidance.[6,7] Such a cover is expected to provide excellent stabilization with the chance of misuse of the radium containing wastes unlikely and erosion avoided for thousands of years.[8]

Using the relationship that soil containing radium with a concentration of 1 pCi/gm has a radon emanation rate of 1 pCi/m^2-sec,[9] a radon emanation rate of 50 pCi/m^2-sec would be expected from the surface of radium containing waste containing radium at a concentration of 50 pCi/gm. Three meters of regular soil cover would reduce that radon emanation rate to approximately 1 pCi/m^2 sec. Such an exhalation rate would be equivalent to average natural background levels as the average concentration of radium in soil is approximately 1 pCi/gm.[10]

This resultant emanation rate is less than that stated in Criterion 1 (5 pCi/m^2-sec). This would allow for accidental removal of a portion of the cover (a little over a meter) before the 5 pCi/m^2-sec level would be exceeded. In the event that an excavation for a basement was made, a significant portion of the "cover" would be removed, resulting in radon emanation rates exceeding 5 pCi/m^2-sec. However, if the cover was designed such that the radium containing waste was capped first with a layer of clay approximately 1.3 feet thick, with the remainder of the cover being regular soil, one could excavate (approximately 8.5 feet) for a basement to within 1.3 feet of the buried radium containing waste without exceeding a resultand radon emanation rate of 5 pCi/m^2-sec.[11]

(NOTE: OSDH may want to consider amending Criterion 2 to incorporate the above design.)

The external gamma radiation levels would be reduced to less than 0.1% of the initial radiation levels with only 1 meter of soil cover[12] (800 mR/yr x 0.001 = 0.8 mR/yr).

It should be noted that the radium containing waste will again be placed in an OSDH permitted landfill with a clay liner to protect against groundwater movement.

In summary, the objectives of this criterion are to guard against accidental intrusion, limit radon emanation, limit external radiation levels, and protect the groundwater.

Criterion 3

"Radium containing waste wastes with radium levels less than 50 pCi/gm (dry weight) may be applied to agricultural cropland or pastureland, but only if the level of the radium in the radium containing waste is such that after the waste is mixed with the soil, the incremental increases of the radium concentration in the soil does not exceed 0.1 picocurie per gram (dry weight)."

The intent of this criterion is to allow radium containing waste to be applied to land used for agricultural cropland or grazing purposes without increasing the radiation exposure significantly.

The normal concentration of radium in soil is approximately 1-2 pCi/gm. The mean daily intake of radium per day (from foodstuffs) in the United States is approximately 1.4 pCi/day.[13] (Water contributes an additional daily uptake of radium.)

The Oklahoma Radiation Protection Regulations, Section 14, Table 3, Column 2,states an exempt concentration for insoluble radium of 3×10^{-5} microcurie/milliliter (μCi/ml. Using a conversion of 1 ml/gm, an exempt concentration of 3 pCi/gm is derived.

The National Council on Radiation Protection and Measurements, Report No. 77, indicates that agricultural land used to produce crops not directly consumed by humans should not exceed a concentration of 40 pCi/gm of Radium 226 in the soil. This is based on a dose limit of 500 mrem/yr to bone (resulting from an average dietary intake of 60 pCi/day of radium) and a plant/soil concentration ratio of 1 x 10^{-3}.[14]

Using the uptake coefficient of 1 pCi/Kg radium in fresh vegetables per 1 pCi/gm radium in the soil, with an average intake of fresh vegetables of 1.5 Kg/day, one would receive an additional 0.15 pCi of radium per day, or 1.25 mrem/yr, by adding 0.1 pCi/gm radium to the soil.[15]

A U.S. Department of Energy pathway analysis report indicates a source-to-dose conversion factor of 21 (mrem/yr)/(pCi/gm) for Radium 226 in soil.[16] Argonne National Laboratory, utilizing the new dosimetry models described in the International Commission on Radiological Protection Publications Numbers 26 and 30, has recalculated this conversion factor to be 28 (mrem/yr)/(pCi/gm) of Radium 226 in soil. As such, an additional 0.1 pCi/gm of radium in soil would result in approximately 3 mR/yr additional dose to an individual based on a worst case scenario.[17]

Sludge applications to land usually would not be more frequent than once every three years. As such, it would take a number of years for the accumulated concentration of radium to increase significantly, and it is unlikely that radium containing waste would be applied to the same fields for an extended period of time.

Criterion 4

"If the level of radium in the radium containing waste exceeds 50 picocuries per gram (dry weight), the method of disposal of such wastes must be approved in advance by OSDH. If such wastes are to be used for soil conditioning and the incremental increase in radium concentration in the soil would exceed the level specified in Paragraph 5 (Criterion 3), such use must be approved in advance by OSDH."

If the levels of radium in radium containing waste to be buried or applied on land for agricultural use exceed those values stated in Criteria 2 or 3, OSDH believes it is necessary to evaluate the final use/disposal of such radium containing waste on a case-by-case basis.

IV. Summary

The above criteria should provide a mechanism for the practical management of radium containing waste containing radium, while at the same time providing assurance that the five technical objectives of OSDH are fulfilled.

REFERENCES

1. USEPA "Final Environmental Impact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, page 9-15.

2. USEPA "Final Environmental Impact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 9-16.

3. USEPA "Final Environmental Impact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 9-15.

4. USEPA "Final Environmental Impact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 8-13.

5. USEPA "Final Environmental Impact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 8-12.

6. USEPA "Final Environmental Inpact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 10-10.

7. USEPA "Final Environmental Inpact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/4-82-013-1, October 1982, Page 91.

8. USEPA "Final Environmental Inpact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 10-3.

9. USEPA "Final Environmental Inpact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 3-5.

10. USEPA "Final Environmental Inpact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 3-5.

11. USEPA "Final Environmental Inpact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 8-10.

12. USEPA "Final Environmental Inpact Statement for the Control of Byproduct Materials from Uranium Ore Processing" (40CFR192), EPA 520/1-83-008-1, September 1983, Page 8-12.

.1 uCi of Ra-226 deposited in the ~~fo~~ bone delivers 0.56 rem/week (ICRP 59)

Dose per uCi = 5.6 Rem/wk = 291 Rem/yr.

Radium deposited ~~in~~ ~~fo~~ the body within a relatively short time (~~month~~ less than 1 year) will decay according to the equation

$$A = A_0 e^{-aT} \quad (1)$$

where A = activity at time = T yr

A_0 = Activity at time 0 yr

$a = \frac{0.693}{T_{1/2}}$

$T_{1/2}$ = Biological half life = 43.84 yr (ICRP 59)

T = Time (in years) since deposition

~~The dose to the bone may be calculated~~

The dose rate to the bone at any given time is

$$D = KA \quad (2)$$

where K = Dose rate per uCi

A = Activity at any time (uCi)

Over the time periods of interest (the remaining lifetime ~~of the exposed individual~~ after exposure of the individual) the ~~one~~ amount of radium in the ~~form~~ bone will be reduced ~~through~~ by the radioactive decay process.

The total accumulated dose is the sum of all the dose since deposition which may be determined by integrating Equation (3) over the time period of interest. This results in the following Table

Time since Deposition (yr)	Total accumulated Dose per uCi Deposited (Rem)
1	364
5	1473
10	2761
20	4699
30	6995
40	8651
50	10124
60	11412
70	12316
~~40~~	

1983
B.C. 19 .6/100,000

$$\frac{\mu Ci/m^3}{\mu Ci/m^2} = 10^{-6}$$ (Brodsky) p ~~374~~ 384

B Rate = 10 m^3/day ~~std~~ (standard man)

~~Retention = 25% to Blood~~

~~Fraction from Gut to Blood~~

Fraction reaching Bone

~~from Blood~~ From ingestion 0.04 (ICRP

~~F~~ From inhalation 0.03 "

μCi in Bone = .04 × μCi ~~swallow~~ ingested

= 0.03 × μCi inhaled

Conc in dirt = 0.001 μCi/gm

assume 1 gm dirt consumed ~~/day~~

~~assume Conc in dirt = 5 pCi/gm = 5×10^{-6} μCi/gm~~

~~50yr dose from 1 gm of dirt = 0.05 Rem~~

Radium Consumed = .001 μCi

Fraction reaching Bone = 0.04 (ICRP 59)

Radium reaching Bone = .001 × 0.04 = 4×10^{-5} μCi

20yr Dose Committment = 0.198 rem

$$Pop = \cancel{3} \; 3.26 \times 10^4 = 0.0326$$

$$Risk = \frac{0.11 \text{ canc}/\text{yr Rem-yr}}{10^6} = 0.11 \times 10^{-6} \frac{\times \text{Rem}}{\text{yR}}$$

$$= \cancel{11} \; 1.1 \times 10^{-7} \times \text{Rem}$$

$$\text{Canc}/\text{yr} = 1.1 \times 10^{-7} \times \text{POP} \times \text{Rem}$$

$$= 1.1 \times 10^{-7} \times 3.2 \times 10^{-2} \times \text{Rem}$$

$$= 3.5 \times 10^{-9} \times \text{Rem}$$

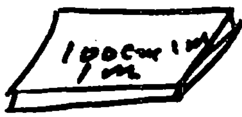
$$=$$

$$\text{Canc}/\text{yr} = \frac{.11 \times .0326 \text{ Rem}}{\cancel{.0326}} =$$

$.71 \times$

$.001\ \mu Ci/gm$

$d = 2.35\ g/cc$



— ~~1 cm 0.001 m~~ 0.1 cm

$\cancel{V = .001\ m^3 = 1000\ cc}$

$W = \cancel{2.35\ Kg}$

$V = 10^2 \times 10^2 \times 10^{-1} = 10^3\ cc$

$W = 2.35 \times 10^3\ gm$

$A = .001 \times 2.35 \times 10^3$

$= 2.35\ \mu Ci/m^2$

$$K = 10^{-6} = \frac{\mu C/m^3}{\mu Ci/m^2}$$

$\mu Ci/m^3 = 2.35 \times 10^{-6}$

Breathing Rate = $10\ m^3/day$

Inhalation = $2.35 \times 10^{-6} \times 10 = 2.35 \times 10^{-5}\ \mu Ci/day$

Time Required = 10 days

Inhalation = $2.35 \times 10^{-5} \times 10 = 2.35 \times 10^{-4}\ \mu Ci$

Fraction reaching bone = 0.03

Amount reaching Bone = $2.35 \times 10^{-4} \times .03$

$= 7.1 \times 10^{-6}\ \mu Ci$

		pCi/M³		μCi/M³
	76			
32	77	0.0091	~~pCi/m³~~	9.1×10^{-9}
4	78	0.0138		13.8×10^{-9}
24	79	0.0095		9.5×10^{-9}
	80	—		

$\bar{x} = 0.0096$ 9.57×10^{-9}